International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 7, Issue 5, Oct 2017, 191-198
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ENHANCEMENT OF HEAT TRANSFER IN SHELL AND TUBE HEAT EXCHANGER BY USING NANO FLUID

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ABSTRACT

Heat transfer rate of TiO_2 and water Nano fluids were measured in a shell and tube heat exchanger under the turbulent flow condition. Even with insignificant focus of Nano particles in the base fluids, results in enhancement of heat transfer coefficient. Heat transfer rate of TiO_2, at its optimum Nano particle concentration are greater than the water particle. From the past research, it is evident that, the addition of Nano particles increases the heat transfer rate. So for the present study, TiO_2Nanoparticles were chosen for dispersing them in the water, for enhancing heat transfer properties and comparing them with only pure base fluid. The current study is also extended to find the overall heat transfer coefficient and the amount of heat transfer enhancement at different flow rates. Further, heat transfer characteristics like Reynolds number and effectiveness were also measured. From the experimental outcomes, it is observed that, there is a clear enhancement in the heat transfer characteristics with addition of Nano particle, at different volume concentrations (0.05%, 0.1%, 0.15% and 0.2%), for different flow rates.

KEYWORDS: Effectiveness, Heat Transfer, Nano Particles, Reynolds Number & Turbulent Flow

Received: Aug 02, 2017; **Accepted**: Aug 21, 2017; **Published**: Sep 15, 2017; **Paper Id.**: IJMPERDOCT201720

Original Article

INTRODUCTION

A heat exchanger is defined as equipment, which transfers the energy from a hot fluid to a cold fluid, with maximum investment and running costs. A heat exchanger is a device used for affecting the process of heat exchange between two fluids, that are at different temperatures. Heat exchangers are useful in many engineering process like those in refrigerating and air-conditioning systems. Power systems, food processing systems, chemical reactors and space or aeronautical applications in heat exchangers, the temperature of each fluid changes as it passes through the exchangers and hence, the temperature of the dividing wall between the fluids, also changes along the length of the exchanger. Heat exchangers are designed to deliver a certain heat transfer rate, for a certain specified condition of flow rates and temperatures. Shell and tube heat exchangers are used, when a process requires large amounts of fluid to be heated or cooled, is suited for higher – pressure applications. There are many different types or designs of shell and tube heat exchangers, to meet various process requirements. Shell and tube heat exchangers come in two (2) and four (4) pass models standard, and multi-pass custom models. Shell and tube heat exchangers use baffles on the shell side fluid, to accomplished mixing or turbulence. Without the use of baffles, the fluid can become stagnant in certain parts of the shell. A comprehensive treatment of heat exchanger design, would involve many factors besides the heat transfer analysis like size, weight, structural length, pressure drop and cost, which is beyond our scope. The rate heat leaves a surface, as a function of temperature difference between the surface and

the ambient. It is denoted by U_0. By increasing the flow rate parameters, effecting the u_0 of No of tubes Velocities in the tube and shell, Tube outside diameter, Baffle spacing, Baffle cut, Length of the tubes, Tube pitch, Logarithmic mean temperature difference.

Nano fluids are two phase mixtures, engineered by dispersing Nano meter sized particles, with sizes ranging below 100 nm in base fluids. The Nano meter sized particles, which are used for the dispersion in base fluids are nano particles, Nano fibers, nanotubes, nanowires and Nano roads. Materials generally used as nano particles, include metal oxides, chemically stable metals, carbon in various forms, metal carbides and functionalized nano particles. The base fluid types include oils, water, organic liquids such as glycols, refrigerants, polymeric solutions, bio fluids, lubricants and other common liquids. Since, solid particles have high thermal conductivity than that of common fluids, when they are dispersed in the fluids, result in more heat transfer characteristics. Nano fluids are stable suspension of Nano metal sized particles, ie smaller than 100nm in at least one dimension, in conventional heat transfer fluids. The most important parameter for heat transfer enhancement is, thermal conductivity. In all the related papers, the experiment results have indicated the enhancement of thermal conductivity by using of nano particles. There are many published studies on the forced convective heat transfer coefficient of Nano fluids, and most of them are under the constant heat flux or constant temperature boundary conditions, at wall of tubes and channels. In shell and tube heat exchangers, the real heat boundary condition is varied, therefore, mentioned boundary conditions and wall temperature and heat flux is not constant. The experimental results for forced convection inside a channel, that shows convective heat transfer coefficient of Nano fluids is enhanced, compared to base fluid.

B. Farajollahi**,** et al. [1], conducted experiments with TiO2 nano particles and the results demonstrated that, the enhancement of thermal conductivity, by addition of nano particles. Hamed Sadighi Dizaji, et al [2], used nano fluids in shell and tube heat exchanger. The energy loss and NTU increase about 17–81% and 34–60%, respectively, over base fluids. Mohammad Hossein Aghabozorg et al [3], found out convective heat transfer of Fe-CNT/ water magnetic Nano fluids, with two concentrations 0.1 and 0.2 wt. % and also measured under different flows (Laminar, Transient and Turbulent), in a horizontal shell and tube heat exchanger. From the stud, the authors observed that, hybrid Fe2O3-CNT magnetic Nano fluids showed higher heat transfer coefficient, compared to the base fluid. Milad Rabbani Esfahani et al [4], conducted their experiments for effect of Nano fluid concentration, flow rates, temperature inlet and flow regime, on the system's energy loss, was studied experimentally. The results showed that, using graphene oxide Nano fluids, as the hot fluid resulted in less energy loss in the shell-and-tube heat exchanger, under both laminar and turbulent conditions. Azher M. Abed, et al [5], concluded from their experiments that, the heat and mass transfer process, on falling film flow and contradictions of thermal physical properties of Nano fluids, should all be taken into careful consideration. In addition, existing research on both heat and mass transfer, regarding Nano fluids are found to be inadequate, and still requires extensive experimental and theoretical work, on their salient parameters. Azher M. Abed et al [6], found out the characteristics of heat and mass transfers, of spray evaporators are still subject to further enhancement. This study is to review the enhancement techniques and falling film flow, especially the effect of nano particles suspended with refrigerants, in order to confirm their role. Ahmad Ghozatloo, et al [7], calculated the convective heat transfer coefficients of grapheme Nano fluids, based on water in the entrance region and under laminar conditions. Also the effect of temperature and concentration, on convective heat transfer coefficients of graphene Nano fluids, has been discussed. Ahmad Ghozatloo et al [8]. The convective heat transfer coefficients of grapheme Nano fluids, based on water in the entrance region and under laminar conditions have been measured. Also, the effect of temperature and concentration on

convective heat transfer coefficients of grapheme Nano fluids, has been discussed. Rohit S et al [9]. The Nano fluids are the mixture of water as base fluid, and TiO2 particles in Nano-range. The results obtained from the Nano fluids cooling, in concentric tube heat exchanger are compared with those from base fluids, as coolant. Effects of inlet flow rate of hot fluids, Reynold's number and composition of Nano fluids, on concentric tube heat exchanger are considered. According to C. L. Undhadet al [10] Energy consumption is the most important problem, in the present day. The energy analysis gives only energy consumption and energy losses of systems. It does not provide information about internal inefficiency of the equipment. V. Rambabuetal[11-15], discussed the various nano fluid blends, with diesel as fuel in IC engines, to increase performance and also studied the different mechanisms of heat transfer enhancement.

REPARATION OF NANO FLUID

Nano fluid preparation is the main step in effective utilization of Nano fluids, in its respective field of application. Single-step method and the other one is two-step method are two methods in preparing Nano fluids. For the present study, two-step method is used. In this study, TiO_2 nano particles dispersed in water. For even distribution of the nano particles in the host medium, and to avoid particle settlement at the bottom of the storage tank, continuous stirring is employed to the Nano fluid system settlement of nano particles. Nano fluid system, after stirring is depicted in the Figure 1. The properties of Nano particles are tabulated in the Table 1

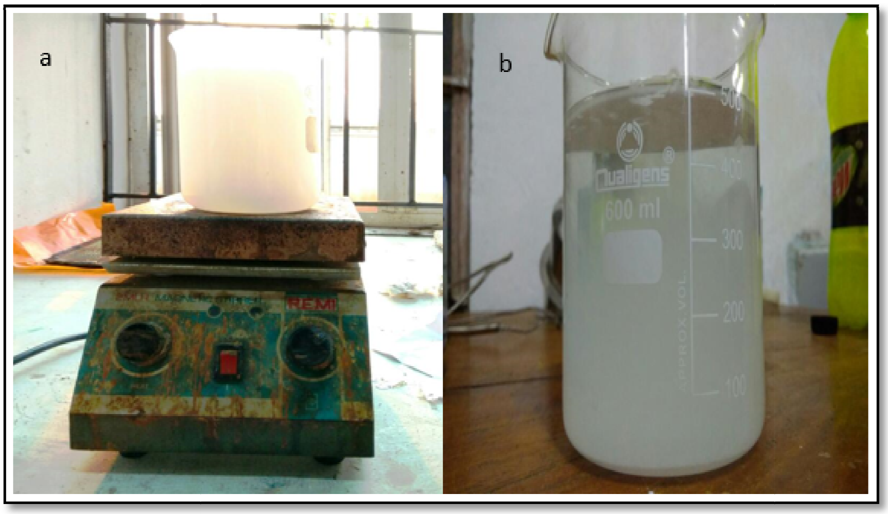

Figure 1a: Nano Fluid System on Stirrer b. Stable Nano Fluid System after Stirring

Table 1: Properties of TiO_2

Property	Corresponding Data
Colour	White
Average particle size	30 – 50nm
Bulk density	0.15 – 0.25 g/cm^3
True density	4.01 g/cm^3
Morphology	Spherical

By using this formula, we can calculate the weight of Nano particles.

$$Volume\ fraction = \frac{Volume\ of\ Nano\ particles}{Volume\ of\ Nano\ particles + Volume\ of\ Base\ fluid}$$

Table 2: Weight of TiO_2 at Various Volume Concentrations

Volumetric Concentrations	Weight of Nano Particle
0.2%	64.48gms
0.15%	48.2gms
0.1%	32.1gms
0.05%	16.05gms

EXPERIMENT SETUP

The shell and tube heat exchanger consist of shell, baffles, tubes, floating head, stationary tube sheet and channels.

Figure 2: Experimental Setup of Shell and Tube Heat Exchanger

Shells are fabricated from steel pipe, with nominal IPS, up to 12 inches Shells are fabricated by rolling steel plate. Baffle is apparently, the higher heat coefficients result, when a liquid is maintained at state of turbulence. To ensure turbulence outside the tubes, it is customary to employ baffles which are because, the liquid flow through the shell at right angles to the axes of the tubes. This causes considerable turbulence, even when a small quantity of liquid flows through the shell. Heat exchanger tubes are also referred to as condensers tubes, and should not be confused with steel pipes or other types of which are extruded to iron pipe sizes, heat exchanger tubes are available in a variety of metals, which include steel, copper, muntz metal, brass. Copper – nickel, aluminum – bronze and stain less steel. Floating head cover is bolted to the tube sheet, and the entire bundle can be withdrawn from the channel end. End channels are typically fabricated and control the flow of the tube side fluid, in the tube circuit. They are attached to the tube sheets, by bolting with a gasket between the two metal surfaces. In this type of heat exchanger, one of the fluid flows through a bundle of tubes, enclosed by a shell. The other fluid is forced through the shell, and it flows over the outer side surface of the tubes, such an arrangement is employed where reliability and heat transfer effectiveness is improved. With the use of multiple tubes, heat transfer rate is improved, due to increasing surface area. Hot water from the greaser is passes through the shells, and cold water is passes through the tubes, by fixing of flow rate and then cold water passes through it and heat transfer takes place. Four thermometers are used, to find the inlet and outlet temperature of hot and cold fluids measures, at different flow rates.

And, used a fan for cooling purpose of Nano fluid. The experimental data were used to calculate the overall heat transfer coefficient, and comparing the results at different volume concentrations of TiO_2 (0.2%, 0.15%, 0.1% and 0.05%).

RESULTS AND DISCUSSIONS

From the experimental investigations it is clear that, at volume concentrations 0.05%, 0.1%, 0.15% and 0.2% the **overall heat transfer coefficient** enhancement, for two flow rates is 7.01% and 15%, 29.1% and 25.9%, 47.5% and 32.2%, 75.9% and 62%, respectively.

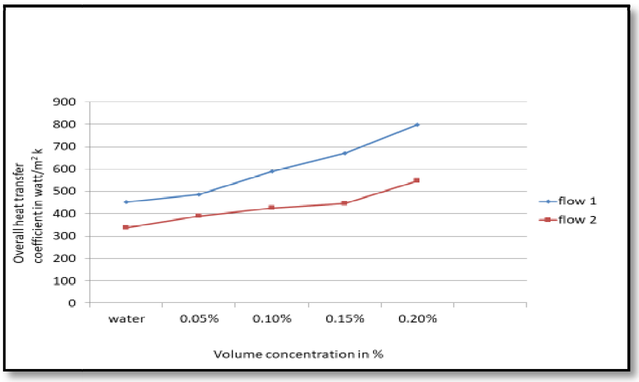

Figure 3: Variation of Overall Heat Transfer Coefficient with Volume Concentration

Apart from overall heat transfer coefficient, we also calculated the heat transfer enhancement. At the volume concentrations 0.05%, 0.1%, 0.15% and 0.2%, for two flow rates, the **heat transfer** enhancement is 19.9% and 49.9%, 40% and 33.3%, 20% and 0%, 60% and 49.9%, respectively.

The graph is drawn between overall heat transfer coefficient and volume concentration. In this graph, at 0.2% of volume concentration, to obtain the maximum overall heat transfer coefficient (U_0) is 798.03 W/m^{2}k.

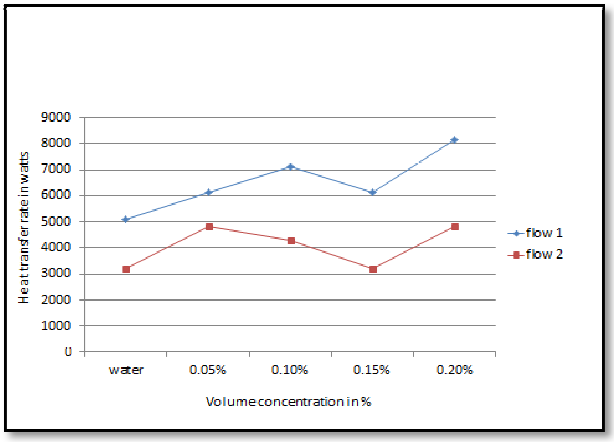

Figure 4: Variation of Heat Transfer Rate with Volume Concentration

In this the graph, drawn between rate of heat transfer and volume concentration in this flow 1, is high flow rate of 0.2443 kg/s, and flow 2 is low flow rate of 0.1286 kg/s. The maximum heat transfer rate is 8161.3 watts, at 0.2% volume concentration.

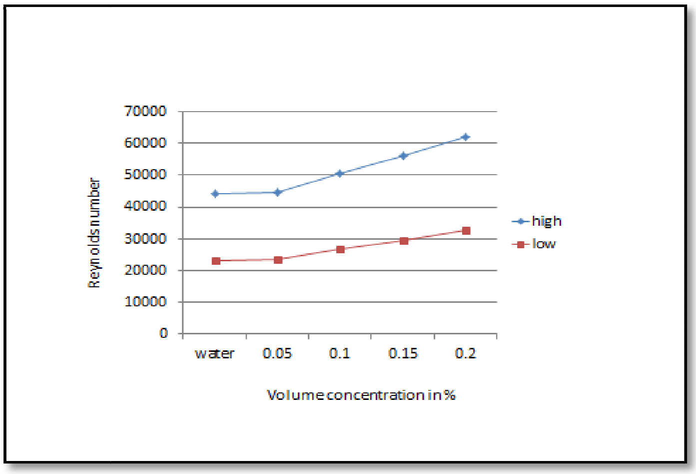

Figure 5: Effect on Reynolds Number Over Volume Concentration Range

In this the graph, it is drawn between Reynolds number and volume concentration. The maximum Reynolds number is 62188.03 at 0.2%, volume concentration.

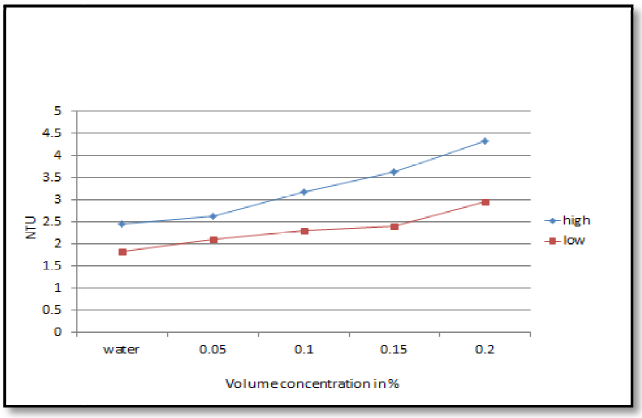

Figure 6: Variation of NTU with Volume Concentration

In this the graph is drawn between NTU and volume concentration. The maximum value is 4.327, at 0.2% volume concentration. By using this formula, we calculated the NTU value.

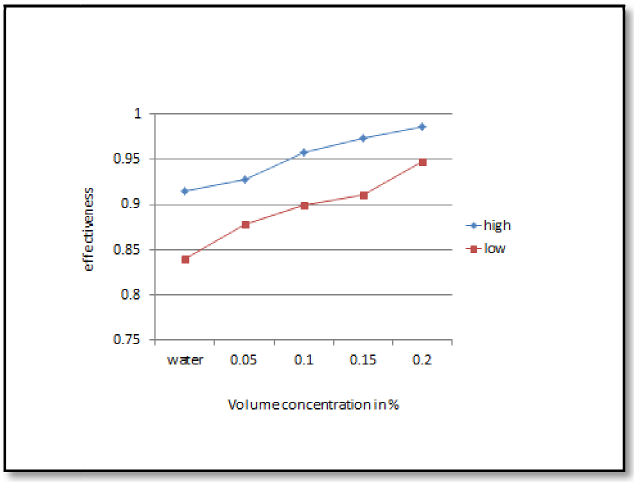

Figure 7: Variation of Effectiveness with Volume Concentration

In this graph, the maximum value of effectiveness is 0.9867, at 0.2% volume concentration. By using this formula, we calculated the effectiveness.

CONCLUSIONS

In the present experimental study, heat transfer behaviour of water and TiO_2 Nano fluid, in a shell and tube heat exchanger was investigated. The experiments were done for a wide range of volume concentrations, of Nano particle. The experiment results for both water and Nano fluids shows that, the heat transfer characteristics of water and Nano fluid improve with volume concentrations of Nano particle. Based on the present experiment results, by adding of Nano particles to the base fluid, cause the heat enhancement of overall heat transfer coefficient.

The overall heat transfer coefficient is increased, with increase in velocity of the fluid in tube. The overall heat transfer coefficient of water is 453.6 watt/m^2 k, and Nano fluid is 798.03 watt/m^2 k. It is observed that, the maximum overall heat transfer coefficient is at 0.2%.

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